“Energy Efficient Framework formulation based on Green Computing for DevOps Automation”

A Synopsis submitted for the registration

DOCTOR OF PHILOSOPHY

In

Computer Science and Application

By

(Nitin Kumar)
Enrollment No. 20660066005

Under the Supervision of

Dr Neeraj Sharma
School of Computer Science & Application

School of Computer Science & Application

IIMT University, Meerut

(July 2021)

1. Introduction

1.1 Green Computing

From the past decade, a lot of focus has been made over energy efficiency of tools/software practices to achieve the green computing objectives. We also have read a lot about the Data centers which are moving to zero emissions. Mostly by their zero emission they do not mean that they don't emit any pollution to the climate by their software, data centers, technological inventions but by zero emission they mean that they are investing the equal amount of green energy within their business use or giving to the society as a charity work. But it is found that the replacement for existing process followed within software development life cycle are less explored. For example, when we try to find the literatures on implementation the Agile delivery model which incorporates a DevOps process that follows on green computing, we could not find much literature. This brings a need of research to be done in these areas. We pick Green computing-based DevOps for our research because this is one of the most common process adopted within all Agile based delivery models. More & more organizations are following DevOps automation to release their codes faster to production, to continuous monitor their

infrastructures and doing other repetitive tasks. The rapid advances in computing and data technology, exemplified by the rise of supercomputers and massive data centers worldwide, have been identified as potential sources of environmental pollution, degradation, and a significant factor in the issue of climate change. The strong drive of businesses to maintain a competitive edge over their peers can be a major force that obscures the judgement of global leaders regarding the potential risks posed by the expanding ICT infrastructure of these large organizations [1]. In recent years, people have noticed the potential growth of green agile research. After studying multiple publications that emphasized the importance of integrating DevOps with Agile methodology, we felt compelled to conduct a comprehensive review to identify potential risks. This unique approach aims to develop a green computing-based DevOps process within an Agile maturity model, and we anticipate it will yield groundbreaking results. [2].

There is less carbon footprint when cloud native applications are used. But we need to identify which all tools can be adopted in keeping the carbon footprint zero or as much minimum possible in Agile Delivery Model for Green computing based devops.

1.2 DevOps

Traditionally in a software development life cycle, there were different team handling the automation in software releases, infrastructure setups, monitoring, capturing metrics etc. With the availability of containerization, creating software release automation, infrastructure as service, software as service etc. many teams were dissolved into one. This one team which now takes care of auto scaling of infrastructure, defining the automation code for continuous monitoring, continuous testing, continuous integration, continuous deployment etc. is now called as DevOps Team. They are a single team involving infrastructure engineers, cloud engineers, automation engineers. Among the software designing exercises, program testing may be a pivotal one which devours more than 50% of add up to taken a toll and time required within the advancement handle. As the effective delivery of the program largely depends on quality, it is imperative to conduct comprehensive testing to achieve it [3]. The Chaos Monkey is a script that runs continuously in all Netflix environments, randomly shutting down server instances to create chaos. As a result, Netflix engineers are constantly working in an unpredictable environment with unexpected outages. This approach not only allows engineers to test their code in unexpected failure scenarios but also encourages them to build resilient systems to make

their work less frustrating. This is the essence of DevOps - transforming the development process and using automation to create a system that incentivizes high-quality software. In response to this kind of environment, Netflix engineers design their systems to be modular, testable, and highly resistant to backend service outages from the beginning [4].

There is a deployment strategy as Green Deployment which is widely used in release deployments. That feature is generally referred to a unique deployment strategy which keeps two identical production environments. Only one environment of them serves traffic. When deployment happens to one environment then slowly the user traffic is moved from older version to newer version of application to reduce the downtime & risk. This strategy is a deployment strategy and must not be confused with Green computing-based DevOps. DevOps process brings the Agile attitude in the software development project. The concept of DevOps involves composing the infrastructure as code and automating processes such as continuous integration, deployment, testing, and monitoring. Agile and DevOps have transformed the way software projects are executed and delivered, with Agile's focus being on meeting client requirements promptly and with minimal defects. Both Agile and DevOps emphasize shared responsibility, automation, and feedback, which ultimately shape team structure [5].

1.3 Agile Delivery Model

In Agile Delivery model, the software project is divided to different Agile Teams. Each of the team then plan the time bound framework to deliver the specific features for planned release of software. It becomes an iterative process until the entire software gets completed in terms of to be delivered with all features. The agile group primarily has three parts: product owner, master and development team. Within the common circumstance, the advancement group individuals require capable for the advancement and test. And in arrange to create their unused highlights or alter portion sends to the client as before long as conceivable, they require an uncommon operations team. In this case, for solving these questions, numerous companies consider adopting DevOps to undertake to move forward the circumstance. DevOps is an improvement approach outlined to bridge the gap between advancement and operations. One good thing about DevOps is the quickened release cycle. With convenient criticism from the end users, program engineers convey items that will be more fulfilling and indeed surprising [6].

An iterative approach is adopted, and a functional software is delivered after every iteration. The release should be incremental with each deployment, incorporating more features until the final build satisfies the customer's requirements. The technology industry is constantly

evolving, offering open-source and proprietary solutions that bring businesses, operations, and software developers closer to their shared goals. Consequently, the industry has seen an increase in practices such as continuous integration (CI), continuous delivery (CDE), and continuous deployment (CD) supported by these solutions. This study represents an initial step towards automating the delivery of resources in a programmable environment by conducting market research and analyzing relevant literature to assess and summarize the current status of CI/CDE/CD [7]. Business organizations and ICT firms consider green computing as a fundamentally portion of their in general trade procedures. From the trade and client viewpoint, the most concern is all about advancement of computer program with no effect on climatic change and feasible advancement [8].

2. Problem Statement

As the more and more software life cycle are following Agile & DevOps process in their delivery model. There is a need to find more suitable Green computing-based approach to reduce the carbon emission as much as possible. Our research will focus over Green computing-based DevOps which would mean we will try to find out the DevOps process/tools so that green computing principles can be adopted in the Agile delivery model-based software development life cycle. With a vast scope of devops, it is required to find out how green computing principles can guide to create a less carbon footprint-based DevOps process that covers Continuous integration, Continuous delivery, Continuous deployment.

3. Objective

The primary focus of this research is to determine the extent to which Green computing principles can contribute to creating a sustainable devops process within the Software development life cycle that is compatible with the Agile Delivery model. It can be accomplished by taking the following small objectives.

- How Green computing principles can be adopted in the DevOps process.
- How Continuous integration, Continuous delivery, Continuous deployment fits well with green computing in Agile model

4. Scope of Study and Hypotheses

Almost all of the software projects are moving the follow or already following the Devops process. Devops is hugely included in automating everything which could be infrastructure as code, software as code, Automation for continuous integration, automation for continuous deployment/delivery/testing/monitoring. As all becoming more or less the part of devops, there is huge opportunity to find out whether we can implement the green computing principles for the devops process. As green computing principles and cloud based resources help to reduce the carbon emission then therefore there is a pressing need to find out if Green computing principles and with available related resources to find out more sustainable devops process.

Integrating environmentally sustainable practices into the DevOps process can lead to reduced carbon footprint and resource consumption while still maintaining or even improving software delivery speed and quality. This can be achieved through various approaches such as optimizing infrastructure utilization, minimizing waste in the software development lifecycle, and leveraging automation and cloud technology to reduce energy consumption. By adopting a DevOps approach with a focus on green computing, organizations can benefit from both operational and environmental efficiencies. However, further research and experimentation are needed to validate this hypothesis and identify best practices for integrating DevOps and green computing.

5. Literature review

After review of different literatures now days in the Green Computing, Agile methodology and DevOps there is a big need for the identification/implementation/ of new framework to achieve all those three together.

1. **“Green Computing Policies and Regulations: A Necessity?” Wilson Nwankwo, Akinola S. Olayinka and Kingsley E. Ukhurebor IJSTR-VOLUME 9**

   The emergence of large data centers and information centers around the world has been attributed to the continuous advancements in computers and data generation, which have been recognized as potential sources of pollution and major contributors to climate change. The drive for peer-to-peer competition among corporations may also conceal the concerns of top executives regarding future risks for emerging ICT organizations. It is important to note that Information Communication Technology (ICT) has played a significant role in the increase of carbon emission.

2. **Developing Green and Sustainable Software using Agile Methods in Global Software Development: Rashid, N. and Khan, S· In Proceedings of the 11th International Conference on Evaluation of Novel Software Approaches to Software Engineering**

   In recent times, there has been a growing recognition of the promising prospects of eco-friendly agile research. The agile delivery techniques prioritize delivering software in response to customers' current needs, but without neglecting its potential long-term impact on individuals and society. Some regions may not have yet achieved the necessary level of agile maturity that would enable them to mitigate risks and foster the development of sustainable green software.

3. **Towards Green Software Testing in Agile and DevOps Using Cloud Virtualization for Environmental Protection, Mala, D. & Reynold, A.**

   Program testing is a crucial aspect of software design that can consume over 50% of the total cost and time of the development process. To ensure successful program delivery, comprehensive testing is essential as it prioritizes quality. Recent studies have highlighted not only the challenges of extensive testing, but also the negative impact on the environment due to the use of dedicated hardware and system resources. In traditional testing environments, quality management and testing tasks are performed in a dedicated setting, which significantly increases carbon emissions.

4. **The DevOps Case Study: Netflix and the Chaos Monkey, C. Cois, Carnegie Mellon University's Software Engineering Institute Blog, April 30, 2015. [Online]**

   Netflix revolutionized their engineering strategy by introducing a tool named Chaos Monkey, which was part of the Chaos Monkey series. The most significant tool in this series was the Netflix Simian Army. Chaos Monkey is a script that runs continuously in all Netflix instances and causes chaos by randomly shutting down server instances. This approach provides an exceptional opportunity for Netflix engineers to test their program in unexpected failure conditions, leading to the development of fault-tolerant systems to make their work less frustrating. This exemplifies DevOps at its best, modifying the development process and using automation to establish a system that incentivizes the creation of high-quality computer programs. To cope with this environment, Netflix engineers design their systems to be isolated, testable, and highly resistant to backend service outages from the outset.

5. **“Project Management in Era of Agile and Devops Methodologies.” Raj, Prixit and Parul Sinha. International Journal of Scientific & Technology Research 9 (2020): 1024-1033.**

   Agile and DevOps have revolutionized the way computer program ventures are executed and delivered. The primary objective of Agile is to meet client requirements in a timely manner with a lower defect rate.

Research has shown that Agile and DevOps strategies have significant impacts on scope management, quality management, and estimation, ultimately affecting the entire project management process. Furthermore, the literature review has also revealed that these methodologies affect shared responsibility, automation, and feedback, which are crucial for team structure. This paper proposes a conceptual framework and hypotheses for future empirical testing to study the holistic impact of these methodologies.

6. **"Adopting DevOps in Agile: Challenges and Solutions" C. Wang and C. Liu, Faculty of Computing, Blekinge Institute of Technology, 371 79 Karlskrona, Sweden,2018**

   The agile group primarily has three parts: product owner, master and development team. Within the common circumstance, the advancement group individuals require capable for the advancement and test. And in arrange to create their unused highlights or alter portion sends to the client as before long as conceivable, they require an uncommon operations team. In this case, for solving these questions, numerous companies consider adopting DevOps to undertake to move forward the circumstance. DevOps is an improvement approach outlined to bridge the gap between advancement and operations. One good thing about DevOps is the quickened release cycle. With convenient criticism from the end users, program engineers convey items that will be more fulfilling and indeed surprising. Despite DevOps is exceptionally cheerful for dispensing with the hole between improvement and operations.

7. **"A Survey of Continuous Integration, Continuous Delivery and Continuous Deployment", Sergejs Bobrovskis, Aleksejs Jurenoks, Institute of Applied Computer Systems, Riga Technical University, Latvia**

   The technology industry is constantly evolving and has provided various open-source and exclusive solutions to bring businesses, operations, and software developers closer to achieving common goals. As a result, advances in technology have increased, leading to the rise of unused practices such as Continuous Integration, Continuous Delivery, and Continuous Deployment (CI, CD, CDE) which are supported by open-source and restrictive arrangements. This study aims to take the first step in planning and developing strategies for automated asset delivery in a programmable environment by conducting market research and analyzing related articles to confirm and summarize the current status of CI/CD/CE.

8. **GREEN SCRUM MODEL: Implementation of Scrum in Green and Sustainable Software Engineering", (IRJET), R M D H LAVANYA**

   Sustainable development is the belief that human societies should be able to fulfill their needs while ensuring the capacity of future generations to fulfill their own needs is not compromised. The Sustainable Advancement Objectives are an all-inclusive call to action to conclusion destitution, secure the planet and make strides the lives and prospects of everybody, all over. Business organizations and ICT firms consider

green computing as a fundamentally portion of their in general trade procedures. From the trade and client viewpoint, the most concern is all about advancement of computer program with no effect on climatic change and feasible advancement.

9. **Readiness model for DevOps implementation in software organizations. Journal of Software Evolution and Process, Rafi, Saima & Wu, & Muhammad, & Azeem Akbar, Muhammad & Mahmood, Sajjad & Alsanad, Ahmed & Gumaei, Abdu & Yu, Wu. (2020)**

   The usage of DevOps practices is basic, and there are no rules to evaluate and make strides the DevOps exercises in computer program organizations. Consequently, there's an ought to create a planned process for DevOps with a point to help the professionals for execution of DevOps process in computer program firms. The DevOps model which was created was based on other well-established models in computer program building space, for illustration, computer program prepares advancement preparation demonstrate (SPIRM) and computer program outsourcing merchant status demonstrate (SOVRM).

10. **Optimization and Prediction Techniques for Self-Healing and Self-Learning Applications in a Trustworthy Cloud Continuum. Inf., Alonso, J., Arrieta, L.O., Osaba, E., Lobo, J.L., Martinez, I., Díaz-de-Arcaya, J., & Etxaniz, I. (2021). 12, 308.2019**

    To fully realize the advantages of IoT services, it is essential for modern technologies to prioritize security measures, including privacy and authentication. While the Internet of Things presents a unique opportunity for economic prosperity and an enhanced quality of life, it also exposes serious security concerns, especially when these devices fall prey to cyber-attacks or hacking. Therefore, implementing appropriate security and authentication solutions is critical for a widespread and swift IoT deployment.

11. **Green IT and Computing: Tool for Sustainable EcoSystems- A Message for Healthy Sports Informatics Practice-Prantosh Kr. Paul1, Ashok Kumar2, Dipak Chatterjee3, Prodipto Das4,Jhuma Ganguly5 and Minakshi Ghosh6,[IIEST], Shibpur**

    Green Data Innovation and Green Computing are at the core of creating a sustainable and environmentally friendly atmosphere through technological advancements, including Database, Mixed media, Organizing, Communication Technology, and more. While electronic items, software processes, and systems play a significant role in our daily lives and business activities, they also contribute to carbon emissions in society. The use of harmful chemicals and materials and excessive carbon outflow are responsible for the negative impact on the environment.

12. **“Greening emerging IT technologies: techniques and practices”, Shuja, J., Ahmad, R.W., Gani, A. et al.,J Internet Serv Appl 8, 9 (2017).**

The phenomenal increase in global industrial activity has resulted in large IT infrastructures, software, live streaming, clouds infrastructure. All the increases in those factors is also resulting the huge carbon emission increase. The concept of Green Computing promotes the energy-efficient and proportional utilization of computing resources, aiming to mitigate the rise of carbon emissions caused by IT and related processes.

13. **Software development methodology in a Green IT environment**, **Hayri Acar, Université de Lyon, 2017**

    According to recent reports by the Intergovernmental Panel on Climate Change (IPCC), ICT (Data and Communication Advances) contributes to approximately 2% of global greenhouse gas emissions, which is similar to that of the aviation industry. Furthermore, the same reports suggest that the CO2 emissions from ICT are increasing rapidly. All things considered, ICT, in permitting to unravel complex issues in other divisions, can significantly and effortlessly take an interest to decrease critical parcel of the remaining 98% of worldwide CO2 emanations. The utilize of computer program suggests equipment operations which are physically mindful of vitality utilization. Thus, computer program is in a roundabout way included within the energy consumption. Thus, we have to be decrease program vitality utilization whereas keeping up the same functionalities for the computer program in arrange to construct economical and green computer program

14. **Green Computing Turns Green IT, IJARCSMS, S. Divya Meena, Volume 4, Issue 2, February 2016, ISSN: 2321-7782 (Online)**

    Green computing is the ponder and hone of ecologically feasible computing. Green Computing hones involve creating, mechanizing, utilizing and arranging of computers capably with irrelevant effect on the climate. Green computing can too be named as Go-Green practice that helps reducing the carbon impression. Green computing encourages us to a secure, secure and sound environment for the mankind.

15. **Energy-Efficient Hybrid Framework for Green Cloud Computing, Alarifi et al. in IEEE Access, vol. 8, pp. 115356-115369, 2020**

    The EEH system arranges clients' requests based on their time and resource requirements before executing the planning process. A planning algorithm takes control consumption into account when making decisions. The system also includes a consolidation algorithm that identifies which servers are underutilized and can be put to rest or hibernation, which are overburdened, and which virtual machines need to be relocated to new servers. Furthermore, the EEH system integrates a migration algorithm for transferring moved virtual machines to new servers.

6. Methodology or work plan

This research will go through of different article analysis. From which different methods will identified for DevOps process for different areas of applications which will be based on Green Computing. This research will complete in these different phases.

Phase 1: Literature Review

Phase 2: The investigation will focus on examining various tools and mechanisms, identifying key issues and challenges, evaluating gaps in existing systems, and exploring different sources of energy. The goal is to discover techniques for improving the DevOps process through the use of Green Computing.

Phase 3: Developing the research objectives, specifically focusing on the problem statement.

Phase 4: Retrieve all possible solutions from previous research for the given objective on the basis of Green Computing

Phase 5: Prepare different devops process aligned with Agile & Green Computing based on research work.

Phase 6: Writing the final report, reviewing the thesis, and submitting it.

Bibliography or references

1. Alonso, J., Arrieta, L.O., Osaba, E., Lobo, J.L., Martinez, I., Díaz-de-Arcaya, J., & Etxaniz, I. (2021). Optimization and Prediction Techniques for Self-Healing and Self-Learning Applications in a Trustworthy Cloud Continuum. Inf., 12, 308.

2. GREEN SCRUM MODEL: Implementation of Scrum in Green and Sustainable Software Engineering, R M D H LAVANYA, e-ISSN: 2395-0056, IRJET, Volume: 07 Issue: 11 | Nov 2020

3. C. Cois, "DevOps Case Study: Netflix and the Chaos Monkey," Carnegie Mellon University's Software Engineering Institute Blog, April 30, 2015. [Online]. Available: http://insights.sei.cmu.edu/blog/devops-case-study-netflix-and-the-chaos-monkey/. [Accessed: October 7, 2021]

4. Raj, Prixit and Parul Sinha. “Project Management in Era of Agile and Devops Methodologies.” International Journal of Scientific & Technology Research 9 (2020): 1024-1033.

5. Erich, Floris & Amrit, Chintan & Daneva, Maya. (2017). A Qualitative Study of DevOps Usage in Practice. Journal of Software: Evolution and Process. 00. 10.1002/smr.1885.

6. Hayri Acar. Software development methodology in a Green IT environment. Other [cs.OH]. Université de Lyon, 2017. English. ffNNT : 2017LYSE1256ff. fftel-01724069f

7. Green Computing Policies and Regulations: A Necessity? Wilson Nwankwo, Akinola S. Olayinka and Kingsley E. Ukhurebor IJSTR-VOLUME 9, ISSUE 01, JANUARY 2020, ISSN 2277-8616

8. Rafi, Saima & Wu, & Muhammad, & Azeem Akbar, Muhammad & Mahmood, Sajjad & Alsanad, Ahmed & Gumaei, Abdu & Yu, Wu. (2020). Readiness model for DevOps implementation in software organizations. Journal of Software Evolution and Process. 33. 10.1002/smr.2323.

9. Green Computing Turns Green IT, IJARCSMS, S. Divya Meena, Volume 4, Issue 2, February 2016, ISSN: 2321-7782 (Online)

10. A. Alarifi et al., "Energy-Efficient Hybrid Framework for Green Cloud Computing," in IEEE Access, vol. 8, pp. 115356-115369, 2020, doi: 10.1109/ACCESS.2020.3002184.

11. Ravi Teja Yarlagadda. "THE DEVOPS PARADIGM WITH CLOUD DATA ANALYTICS FOR GREEN BUSINESS APPLICATIONS", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Vol.7, Issue 3, pp.660-664, August 2019, URL: http://www.ijcrt.org/IJCRT1133973

12. Harmon, Robert & Auseklis, Nora. (2009). Sustainable IT services: Assessing the impact of green computing practices. PICMET: Portland International Center for Management of Engineering and Technology, Proceedings. 1707 - 1717. 10.1109/PICMET.2009.5261969.

13. S. Godboley, A. Dutta, B. Besra and D. P. Mohapatra, "Green-JEXJ: A new tool to measure energy consumption of improved concolic testing," 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), 2015, pp. 36-41, doi: 10. 1109/ICGCIoT.2015.7380424.

14. Anderson E, Lim SY, Joglekar N (2017) Are more frequent releases always better? dynamics of pivoting, scaling, and the minimum viable product. In: Proceedings 50th Hawaii international conference on system sciences, pp 5849–5858

15. Callanan M, Spillane A (2016) DevOps: making it easy to do the right thing. IEEE Softw 33(3):53–59

16. Lwakatare LE (2017) DevOps Adoption and Implementation. In: Software development practice, concept, practices, benefits and challenges. Acta Universitatis Ouluensis, 2017 ISBN 978-952-62-1710-9

17. Mala, D. & Reynold, A.. (2020). Towards Green Software Testing in Agile and DevOps Using Cloud Virtualization for Environmental Protection. 10.1007/978-3-030-33624-0_11.

18. Dick, Markus & Drangmeister, Jakob & Kern, Eva & Naumann, Stefan. (2013). Green software engineering with agile methods. 2013 2nd International Workshop on Green and Sustainable Software, GREENS 2013 - Proceedings. 78-85. 10.1109/GREENS.2013.6606425.

19. Ghantous, Georges Bou and Gill, Asif, "DevOps: Concepts, Practices, Tools, Benefits and Challenges" (2017). PACIS 2017 Proceedings. 96.

20. Shuja, J., Ahmad, R.W., Gani, A. et al. Greening emerging IT technologies: techniques and practices. J Internet Serv Appl 8, 9 (2017). https://doi.org/10.1186/s13174-017-0060-5

21. Raza, Khalid & Patle, V. & Arya, Sandeep. (2012). A Review on Green Computing for Eco-Friendly and Sustainable IT. J. Comput. Intell. Electron. Syst.. 1. 3-16. 10.1166/jcies.2012.1023.

22. Paul, P.K. & Kumar, Ashok & Chatterjee, Dipam & Das, Prodipto & Ganguly, Jhuma & Ghosh, Minakshi. (2016). Green IT and computing: Tool for sustainable eco systems- A message for healthy sports informatics practice. TechnoLearn: An International Journal of Educational Technology. 6. 73. 10.5958/2249-5223.2016.00011.5.

23. S.V.S.S. Lakshmi, Ms. I Sri Lalita Sarwani, M.Nalini Tuveera / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue4, July-August 2012, pp.1282-1285

24. C. Wang and C. Liu, “Adopting DevOps in Agile: Challenges and Solutions,” Dissertation, 2018.

25. Rashid, N. and Khan, S. Developing Green and Sustainable Software using Agile Methods in Global Software Development: Risk Factors for Vendors. In Proceedings of the 11th International Conference on Evaluation of Novel Software Approaches to Software Engineering (ENASE 2016), pages 247-253 ISBN: 978-989-758-189-2

26. Bobrovskis, S., & Jurenoks, A. (2018). A Survey of Continuous Integration, Continuous Delivery and Continuos Deployment. BIR Workshops.